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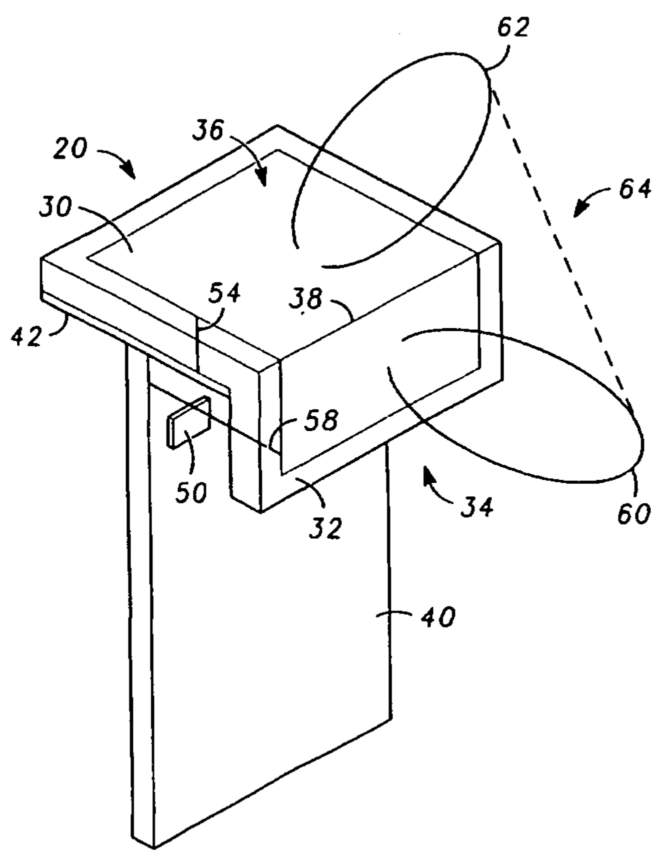
(54) Title: FOLDED INVERTED F ANTENNA FOR GPS APPLICATIONS



(57) Abstract: A folded inverted F antenna (FIFA) (20) includes an L-shaped receiving element (30) having a first planar portion (34) and a second planar portion (36) connected along a fold edge (38). A printed circuit board (PCB) (40) is disposed perpendicular to the second planar portion (36) forming a PCB ground plane. The FIFA includes a second ground plane (42) disposed below and arranged approximately in parallel with the second planar portion (36). At least one shorting conductor (54) couples the receiving element (30) to at least one of the PCB and second ground planes (40, 42). At least one receive conductor (58) couples a receiver circuit (50) to the receiving element. The FIFA is adapted for use in a wireless communication device, such as a cellular phone, for receiving position signals from a global positioning system (GPS) satellite. The FIFA exhibits an enhanced sensitivity field to electric and magnetic fields traveling along a zenith direction and greater antenna gain than conventional planar inverted F antennas (PIFA).

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

FOLDED INVERTED F ANTENNA FOR GPS APPLICATIONS

The present invention relates to antennas for use in portable, wireless, communication devices and more particularly to antennas for receiving global positioning system (GPS) signals.

Background Art

Planar Inverted F Antennas (PIFA) are widely used in cellular telephone handsets for the transmission and reception of radio frequency (RF) signals to and from base stations. A prior art PIFA is shown in FIG. 1. A conventional PIFA 10 typically include a plate conductor and a ground conductor which are arranged approximately in parallel. The plate and ground conductors are typically coupled by a shorting pin (not shown), while a coaxial line is typically employed as a feed pin (also not shown).

Because a PIFA is a planar antenna, it is usually parallel-mounted to the printed circuit board (PCB) 12 ground plane. Due to the small size of the cellular phone handset, only the first resonating mode of the PIFA is typically used for antenna radiation. The direction of the radiating maximum 14 for the first resonant mode is perpendicular to the plane of the antenna, as shown.

In addition, PIFAs have been used in stand-alone global positioning system (GPS) applications. In GPS applications, the PIFA is typically mounted on top of a car or stand-alone box, so that it is generally parallel to the earth plane. In this orientation, the direction of the radiating/receiving maximum is perpendicular to the earth plane i.e. pointing toward the sky, from where the GPS signals are transmitted.

With the enactment of FCC regulations governing the establishment of emergency (E911) telephone calls from cellular telephones, cellular telephones are now required to possess a GPS chip or geolocation receiver, and to be capable of receiving GPS position data transmitted by a GPS satellite. The presence of a GPS chip in a cellular telephone or other portable wireless

communication device allows a user to press a 911 or panic button if the user is in danger or in need of medical attention. The portable wireless device would then resolve positioning signals from a number of GPS satellites. A location signal is then transmitted from the wireless device to police, fire or medical emergency personnel so that the user may be located easily.

If a PIFA is used to receive GPS signals, it is usually mounted parallel to the PCB ground plane, like in other cellular applications. However, a cellular telephone is typically held in a generally vertical position when being used. In this position, the PIFA's radiating/receiving maximum is directed toward the horizon and its radiating/receiving minimum is directed toward the sky. Typically, the antenna gain for a PIFA is 10 dB lower in the direction of the radiating/receiving minimum as in the direction of the radiating/receiving maximum. Therefore, using a PIFA to receive GPS signals results in poor communication links or dropped calls. One potential solution to this problem is to mount an entire PIFA on the top of the cellular telephone housing so that its radiating/receiving maximum points toward the sky. However, the smaller cellular phone housings which are now used do not contain sufficient space to support a PIFA mounted in this way. Therefore, a need exists for an inverted F antenna that can effectively receive position signals from GPS satellites.

The present invention contemplates a new and improved inverted F antenna for receiving GPS signals which overcomes the above-referenced problems and others.

Brief Description of Drawings

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the invention.

FIGURE 1 is a perspective view of a conventional PIFA mounted to a printed circuit board (PCB) of a cellular telephone;

FIGURE 2 is a perspective view of a folded inverted F antenna (FIFA) in accordance with the present invention;

FIGURES 3A, 3B, and 3C are perspective views of alternate embodiments of a FIFA in accordance with the present invention; and

FIGURE 4 is a perspective view of an alternate embodiment of a FIFA capable of transmitting/receiving circularly polarized signals in accordance with the present invention.

Disclosure of Invention

With reference to FIGURE 2, the folded inverted F antenna (FIFA) 20 of the present invention includes an L-shaped or folded conductor plate, which forms the receiving element 30 for the antenna 20. Preferably, the receiving element 30 is mounted on a dielectric substrate 32. Because antennas are reciprocal devices, it is to be appreciated that the conductor plate 30 may serve as a radiating element for transmitting radio frequency (RF) signals and/or a receiving element for detecting RF signals. The receiving element 30 consists of a parallel side 34 and a perpendicular side 36 which share a fold edge 38. Preferably, the fold angle between the parallel and perpendicular sides is about 90 degrees. However, it is to be appreciated that the fold angle of the receiving element may have values less than or greater than 90 degrees. The folded radiating/receiving element 30 is mounted on top of a printed circuit board (PCB) ground plane 40 such that the parallel side 34 is parallel to the PCB and the perpendicular side 36 is perpendicular to the PCB, as shown in FIGURE 2. Such a PCB is standard in cellular telephones and other wireless communication devices. The implementation of the present invention will be discussed in terms of cellular telephones. However, it is to be understood that a FIFA may be employed in other wireless communication devices such as personal digital assistants (PDA) and standalone GPS stations.

A separate antenna ground plane 42 is disposed below and substantially parallel to the perpendicular side 36 of the receiving element 30. In one embodiment, the PCB 40 serves as a ground plane for the parallel side 34. In an alternate embodiment, a separate ground plane (not shown) is mounted substantially parallel to the parallel side 32 in addition to the

PCB. It should be appreciated that the FIFA exhibits better bandwidth in the embodiment in which the PCB serves as the ground plane for the parallel side.

In the embodiment of FIGURE 2, where the PCB serves as the ground plane for the parallel side, a receiver circuit 50 is disposed between the parallel side 34 and the PCB ground plane 40. Utilizing the space between the parallel side and the PCB ground plane to house antenna circuitry or components contributes to overall real estate efficiency, which facilitates using the present invention in smaller telephone housings.

The FIFA includes at least one shorting pin or conductor 54 which couples the L-shaped receiving element 30 to the first ground plane 42 and/or the PCB ground plane 40. In addition, a receive conductor or receive line 58 couples the antenna's receiver circuit 50 to the receiving element 30. Preferably, coaxial cable, containing an inner conductor and an outer ground shield, is utilized as the receive conductor. It is to be appreciated that positioning of the shorting conductor and receive conductor affects the performance of the antenna. FIGURES 3A, 3B, and 3C illustrate alternate embodiments of shorting and receive conductor positions for the FIFA. FIGURE 3A illustrates an embodiment with both the shorting and receive conductors 54 and 58, respectively, coupled to the parallel side 34 of the receiving element 30. FIGURE 3B illustrates an alternate embodiment in which the receive conductor 58 is coupled to the perpendicular side 36 of the receiving element 30 and the shorting conductor 54 is coupled to the parallel side 34 of the receive element 30. FIGURE 3C illustrates yet another embodiment where both the shorting and receive conductors 54, 58 are coupled to the perpendicular side 36 of the receiving element 30. It is to be appreciated that antenna performance for each of the aforementioned embodiments may be varied by changing the position of the receive and/or shorting conductors on the parallel and/or perpendicular sides of the receiving element.

Referring back to FIGURE 2, as will be discussed more fully below, the shorting and receive conductors, 54 and 58, respectively, are adjusted in order to achieve maximal

sensitivity to electric and magnetic fields transmitted by a global positioning system (GPS) satellite. Because of the location of the GPS satellite above the surface of the earth, the transmitted GPS signals travel along a zenith direction, i.e. from the sky.

More particularly, the geolocation receiver 50 and associated FIFA antenna 20 provide the wireless device with embedded GPS capability. GPS capability means the ability to self determine position through the use of the GPS constellation of satellites. The Global Positioning System (GPS) may be used to determine the position of a GPS receiver on or near the surface of the earth from signals received from a constellation of satellites. The orbits of the GPS satellites are arranged in multiple planes in order that signals can be received from at least four satellites at any position on earth. More typically, signals are received from six or eight satellites at most places on the earth's surface. Orbits of GPS satellites are determined with accuracy from fixed ground stations and are relayed to the spacecraft. The latitude, longitude, and altitude of any point close to the surface of the earth can be calculated from the times of propagation of the electromagnetic signals from four or more of the satellites.

A measured range, referred to as a "pseudorange", is determined between the GPS receiver and the satellites based upon these propagation times. The measured range is referred to as pseudorange because there is typically a time offset between timing clocks on the satellites and a clock within the GPS receiver. To determine a three-dimensional position, at least four satellite signals are needed to solve for the four unknowns represented by the time offset and the three dimensional position. The nature of the signals transmitted from the GPS satellites is well known from the literature.

Each GPS satellite transmits two spread spectrum, L-band carrier signals, referred to as L1 and L2 signals. Two signals are needed if it is desired to eliminate any error that arises due to refraction of the transmitted signals by the ionosphere. The L1 signal from each GPS satellite is Binary Phase Shift Keyed

(BPSK) modulated by two pseudorandom codes in phase quadrature as is known to those skilled in the art.

Using a binary pseudorandom code to modulate the phase of a carrier signal produces a suppressed carrier spread spectrum signal. The L2 signal from each satellite is BPSK modulated by only one of the pseudorandom codes. Use of the pseudorandom codes allows use of a plurality of GPS satellite signals for determining a receiver's position and for providing navigation information. A signal transmitted by a particular GPS satellite is selected by generating and matching, or correlating, the pseudorandom code for that particular satellite. Some of the pseudorandom codes are known and are generated or stored in GPS receivers. Other pseudorandom codes are not publicly known.

Referring again to FIGURE 2, both the parallel side 34 and the perpendicular side 36 of the receiving element 30 have radiation sensitivity maxima 60, 62 in directions perpendicular to the parallel and perpendicular sides. In other words, with the cellular phone oriented generally vertically, the parallel side 34 of the receiving element 30 possesses a radiation sensitivity maximum 60 in the horizon direction and the perpendicular side 36 of the receiving element 30 possesses a radiation sensitivity maximum 62 in the zenith direction. These two radiation sensitivity maxima 60, 62 form a continuous radiation sensitivity field 64. Preferably, the radiation sensitivity field of the FIFA is tuned to receive GPS position signals when the cellular phone is in a user position ranging from about vertical to about 30 degrees from about vertical.

The positioning of the receive conductor 58 and the shorting conductor 54 may be varied depending upon the physical geometry of the wireless device housing. For example, a FIFA for use in a type cellular phone that has a movable section that opens and closes relative to the body of the telephone will have different positioning of the receive and shorting conductors that a conventional 'candy bar' style cellular telephone. In other words, the contact positions of the receive conductor 58 and the shorting conductor 54 on the parallel side 34 and the perpendicular side 36 of the receiving element are varied in

order to adjust the overall radiation sensitivity maximum so that it is pointing toward the sky or zenith direction regardless of the orientation of the cellular telephone. Preferably, the radiation sensitivity field is tuned such that GPS signals will be within the radiation sensitivity maximum for cellular phone orientations from about vertical to about 30 degrees from about vertical. The FIFA 20 exhibits about 6dB greater antenna gain for signals in the zenith direction than conventional planar inverted F antennas.

With continuing reference to FIGURES 3A-3C, the FIFA configurations having one receive pin 58 and one shorting pin 54 (FIGURES 3A-3C) provide an antenna which is capable of receiving linearly polarized (LP) signals. GPS satellites transmit circularly polarized (CP) signals. However, any CP field transmitted by a GPS satellite can be decomposed into two orthogonal LP fields having a 90 degree phase difference, with one of the two LP fields matching the polarization of the FIFA antenna.

With reference to FIGURE 4 and continuing reference to FIGURES 3A-3C, in an alternate embodiment, a FIFA is configured to transmit/receive CP signals by employing two shorting conductors 54_1, 54_2 and one receive conductor 58 on the receiving/radiating element 30. In one embodiment, a receive conductor 58 is in contact with the receiving element 30 at the fold edge 38. As shown in FIGURE 4, one shorting conductor 54_2 is coupled to the parallel side 34, while the other shorting conductor 54_1 is coupled to the perpendicular side 36. By adjusting the relative positions of the shorting conductors, the FIFA is tuned to change the strength and phase of its sensitivity/radiating field, such that CP fields may be received/transmitted in desired directions. It is to be appreciated that CP fields may be detected/transmitted by coupling two receive conductors, one on each of the parallel and perpendicular sides, and a single shorting conductor to the receiving/radiating element.

What is claimed is:

Claims

1. An antenna device for a portable wireless device, the antenna device comprising:

a first ground plane;

a first conductor plane oriented substantially parallel with the first ground plane;

a second ground plane oriented substantially perpendicular to the first ground plane and first conductor plane;

a second conductor plane oriented substantially parallel with the second ground plane;

a shorting conductor extending between at least one of i) the first ground plane and first conductor plane, and ii) the second ground plane and second conductor plane; and

at least one receive conductor extending between a receive circuit and at least one of i) the first conductor plane and ii) the second conductor plane.

2. The device of claim 1, wherein the first ground plane defines a printed circuit board (PCB) of the wireless device.

3. The device of claim 2, wherein the first conductor plane is spaced apart from the first ground plane to define an area on the printed circuit board for locating wireless device circuitry.

4. The device of claim 1, wherein the first conductor plane and the second conductor plane are joined at mutual edges thereof to define a fold edge.

5. The antenna device according to claim 4, wherein:

the receive conductor couples the receive circuit to the fold edge of the first and second conductor planes;

a first shorting conductor connects the first conductor plane to the first ground plane; and

a second shorting conductor connects the second conductor plane to the second ground plane.

6. The antenna device according to claim 5, wherein the first and second conductor planes receive circularly polarized electric and magnetic radiation fields transmitted by a global positioning system (GPS) satellite.

7. The antenna device according to claim 1, wherein:

the first conductor plane is maximally sensitive to electric and magnetic radiation fields in a horizon direction; and

the second conductor plane is maximally sensitive to electric and magnetic radiation fields in a zenith direction.

8. The antenna device according to claim 7, wherein the receive and shorting conductors are positioned on the first and second conductor planes in order to receive radio frequency signals from a global positioning system (GPS) satellite.

9. The antenna device according to claim 1, wherein the receive conductor is a coaxial line having an inner conductor and an outer conductor, where the inner conductor couples at least one of the first and second conductor planes and the receive circuit.

10. In a wireless communications system, a method for receiving signals from a global positioning system (GPS) using a portable wireless device, the method including:

positioning an L-shaped receiving element within the portable wireless device such that a perpendicular plane of the receiving element is directed toward a zenith direction and a parallel plane of the receiving element is directed toward a horizon direction;

coupling the receiving element to at least one of a first ground plane and a second ground plane using a shorting conductor;

coupling the receiving element to a receiver circuit using a receive conductor; and

maximizing sensitivity to GPS signals traveling along the zenith direction.

11. The method according to claim 10, wherein the maximizing step includes:

adjusting the positions of the shorting and receive conductors depending on the geometry of the portable wireless device.

12. The method according to claim 11, wherein the shorting and receive conductors are positioned in order to maximize radiation sensitivity to electric and magnetic fields traveling in

directions ranging from parallel to the zenith direction to 30 therefrom.

13. An inverted F antenna for use in a portable wireless communications device capable of receiving signals from a global positioning system (GPS), the antenna comprising:

a printed circuit board (PCB) ground plane having a first planar surface and a top edge;

an L-shaped receiving element having a first planar portion parallel to the PCB planar surface and a second planar portion perpendicular to the PCB planar surface, the first and second planar portions connected along a fold edge;

a second ground plane disposed below and arranged approximately in parallel with the second planar portion;

at least one shorting conductor which couples the L-shaped receiving element to at least one of the PCB and second ground planes; and

at least one receive conductor which couples the L-shaped receiving element to a receiver circuit.

14. The inverted F antenna according to claim 13, wherein the first planar portion is approximately parallel to and spaced apart from the PCB ground plane.

15. The inverted F antenna according to claim 14, wherein the receiver circuit is disposed between the spaced apart PCB ground plane and the first planar portion.

16. The inverted F antenna according to claim 15, wherein:

the receive conductor couples the receiver circuit to the fold edge of the receiving element;

a first shorting conductor couples the first planar portion to the PCB ground plane; and

a second shorting conductor couples the second planar portion to the second ground plane.

17. The inverted F antenna according to claim 15, wherein the shorting conductor and receive conductor are positioned on the receiving element in order to maximize radiation sensitivity in to electric and magnetic fields traveling along a zenith direction.

18. An antenna for a portable device comprising:

a printed circuit board (PCB) having a PCB planar surface and a top edge; and

a radiating element including,

a first planar portion oriented parallel to the PCB planar surface, and

a second planar portion oriented perpendicular to the PCB planar surface, the first and second planar portions connected along a fold edge.

19. The antenna according to claim 18 wherein at least a portion of the PCB comprises a ground plane.

20. The antenna according to claim 18 further comprising a ground plane oriented parallel to any of the first planar portion and the second planar portion.

21. The antenna according to claim 20 wherein the ground plane is electrically coupled to any of the first planar portion and the second planar portion.

22. A cellular telephone comprising:

a printed circuit board (PCB) having a PCB planar surface and a top edge; and

a radiating element including,

a first conductive planar portion oriented parallel to the PCB planar surface, and

a second conductive planar portion oriented perpendicular to the PCB planar surface, the first and second conductive planar portions connected along a fold edge.

23. The cellular telephone according to claim 22 wherein the radiating element is located near the top edge.

24. The cellular telephone according to claim 22 further comprising a ground plane oriented parallel to any of the first conductive planar portion and the second conductive planar portion.

25. The cellular telephone according to claim 22 further comprising a Global Positioning System (GPS) receiver electrically coupled to the radiating element.

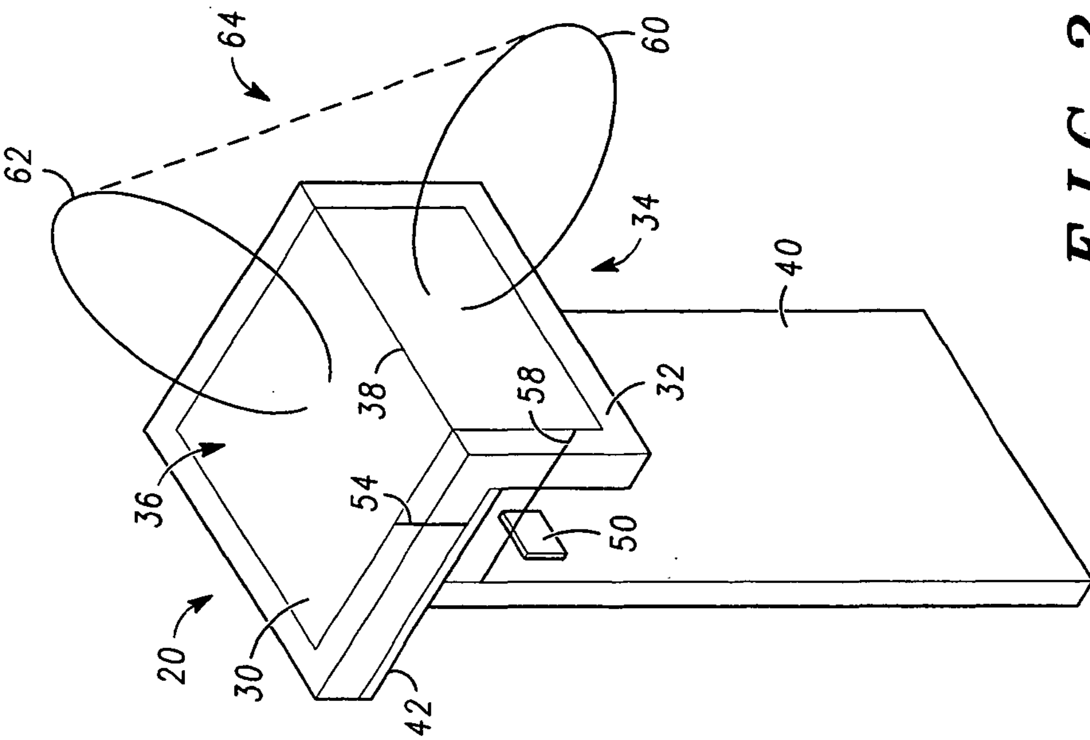

FIG.2

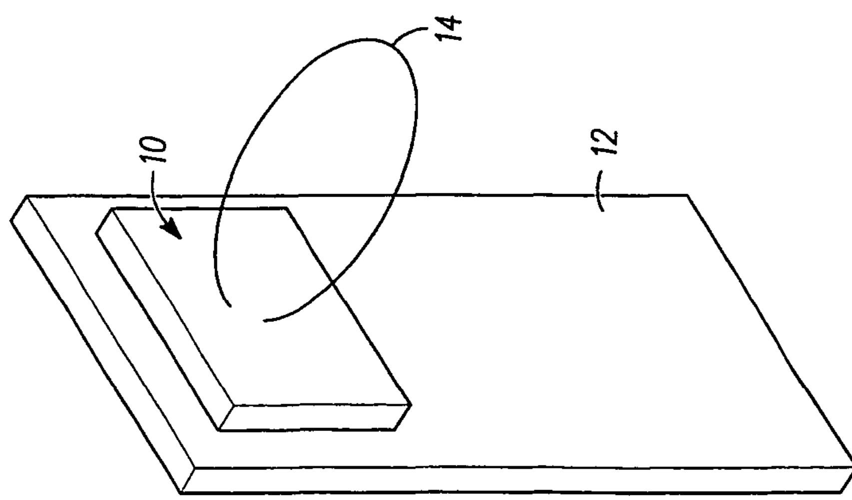

FIG.1
—PRIOR ART—

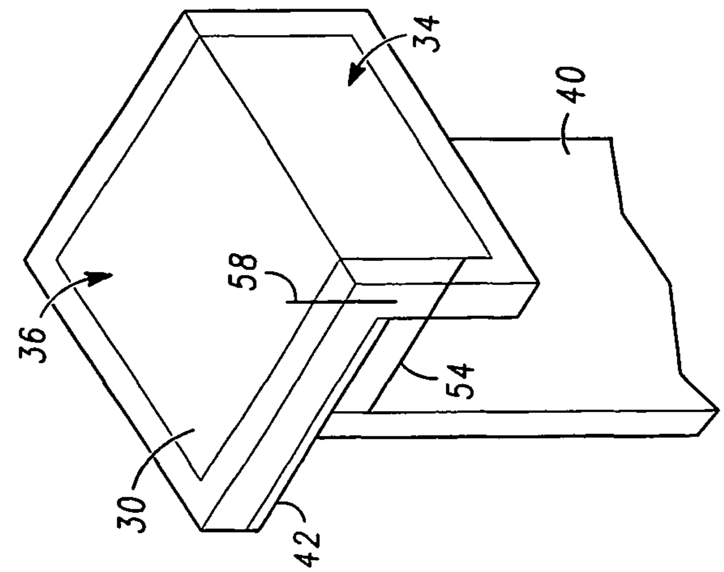

FIG.3B

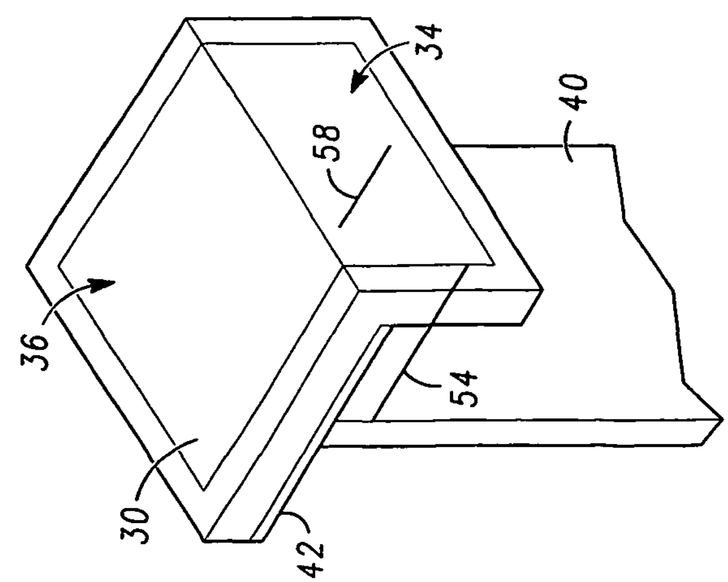

FIG.3A

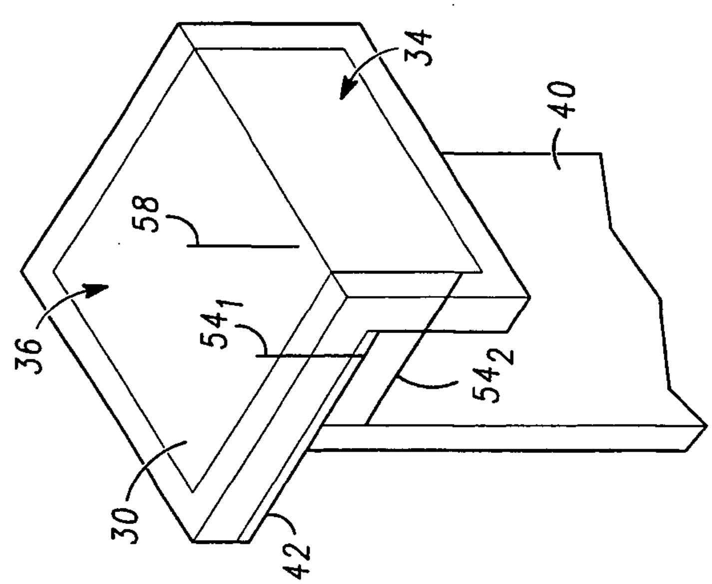

FIG.4

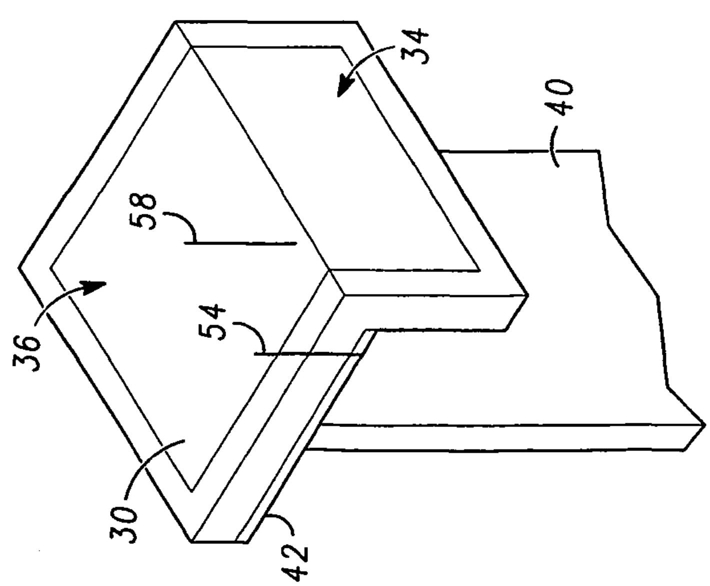

FIG.3C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/30804

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04B 1/38
US CL : 455/90
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 455/90; 343/770, 769

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,539,420 A (DUSSEUX, et al) 23 July 1996, All	1-21
A	US 6,052,093 A (YAO, et al) 18 April 2000, All	1-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 01 February 2002 (01.02.2002)	Date of mailing of the international search report 21 FEB 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer WILLIAM D. CUMMING Telephone No. 703-306-0377

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/30804

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1-21

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

Group I, claims 1-21, drawn to drawn to an antenna device.

Group II, claims 22-25, drawn to a cellular telephone.

The inventions listed as Groups I and II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:
Group I is directed to an antenna which does not share special technical features of Group II, a cellular telephone. Also the antenna could be also used on other portable wireless devices, just not cellular telephones.